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DEVELOPMENT OF A 2,000-10,000-LB IMPROVED CONTAINER DELIVERY SYSTEM

by
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14. ABSTRACT

This paper discusses the details of a program to develop and test a family of Improved Container Delivery Systems (ICDS) capable of airdropping 2,000-10,000-lb payloads, the intricacies of developing a parachute model of the Joint Precision Airdrop System – Mission Planner (JPADS-MP), and the results from testing. The systems are being developed by the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) in conjunction with the Joint Improvised Explosive Device Defeat Organization (JIEDDO). They were designed to be low cost and one time use and to use components already in the U.S. Army inventory. Readily available parachutes were used, and a low cost plywood platform was designed, submitted, and approved for use on U.S. Air Force C-17 and C-130E/H/J model aircrafts. These ballistic parachute systems use a high altitude low opening (HALO) design to meet the threshold requirement of 400 m accuracy when airdropped from an altitude of 24,500 ft Mean Sea Level (MSL). The wireless activation device (WAD) is a key component of these systems and is responsible for the staging of the low opening parachutes. This device is wirelessly programmed for a specific time period, calculated based on weather and parachute characteristics using the JPADS-MP. Empirical data such as rate of descent as a function of weight and altitude, stabilization time, altitude loss, forward throw, and inflation times for each system configuration were collected during test drops. A database was generated for each parachute configuration and this data was combined with pre-existing parachute data to build system models into the JPADS-MP.

15. SUBJECT TERMS

RISK	AIRCRAFT	EXPENDABLE	TRANSPORT AIRCRAFT
CARGO	PAYLOADS	HIGH ALTITUDE	REUSABLE EQUIPMENT
CONVOY	ACCURACY	AERIAL DELIVERY	TEST AND EVALUATION
PALLETS	LOW COSTS	ARMY PERSONNEL	AIR DROP OPERATIONS
AIRDROP	CONTAINERS	PRECISION AIRDROP	HALO(HIGH ALTITUDE LOW OPENING)
HAZARDS	PARACHUTES	LOGISTICS PLANNING	

ICDS(IMPROVED CONTAINER DELIVERY SYSTEM)

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Development of a 2,000-10,000-Lb Improved Container Delivery System

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The U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) has been working in conjunction with the Joint Improvised Explosive Device Defeat Organization (JIEDDO) to develop a family of Improved Container Delivery Systems (ICDS) capable of airdropping 2,000-10,000-lb payloads. The systems were designed to be low cost and one time use and to use components already in the U.S. Army inventory. Readily available parachutes were used, and a low cost plywood platform was designed, submitted, and approved for use on U.S. Air Force C-17 and C-130E/H/J model aircrafts. These ballistic parachute systems use a high altitude low opening (HALO) design to meet the threshold requirement of 400 m accuracy when airdropped from an altitude of 24,500 ft Mean Sea Level (MSL). The wireless activation device (WAD) is a key component of these systems and is responsible for the staging of the low opening parachutes. This device is wirelessly programmed for a specific time period, calculated based on weather and parachute characteristics using the Joint Precision Airdrop System – Mission Planner (JPADS-MP). Empirical data such as rate of descent as a function of weight and altitude, stabilization time, altitude loss, forward throw, and inflation times for each system configuration were collected during test drops. A database was generated for each parachute configuration and this data was combined with pre-existing parachute data to build system models into the JPADS-MP. This paper discusses the details of the program, the intricacies of developing a parachute model of the JPADS-MP, and the results from testing.

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Nomenclature

“	=	Inches
AGL	=	Above Ground Level
CARP	=	Computed Aerial Release Point
CDS	=	Container Delivery System
CEP	=	Circular Error Probable
ft	=	Feet
fps	=	Feet Per Second
HALO	=	High Altitude Low Opening
HV	=	High Velocity
ICDS	=	Improved Container Delivery System
IED	=	Improvised Explosive Device
IP	=	Impact Point
JIEDDO	=	Joint Improvised Explosive Device Defeat Organization
JPADS-MP	=	Joint Precision Airdrop System – Mission Planner
LAR	=	Launch Acceptability Region
LCADS-HV	=	Low Cost Airdrop System – High Velocity
LCADS-LV	=	Low Cost Airdrop System – Low Velocity
LV	=	Low Velocity
m	=	Meters
MSL	=	Mean Sea Level
NSRDEC	=	Natick Soldier Research Development and Engineering Center
RS	=	Ring Slot
TSPI	=	Time, Space, Position Information
WAD	=	Wireless Activation Device

I. Introduction

The U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) with the sponsorship of the Joint Improvised Explosive Device Defeat Organization (JIEDDO) developed the 10K Improved Container Delivery System (ICDS) to deliver supplies in the warzone while reducing the number of convoys. Data collected overseas showed over 300,000 pallets were trucked per month to forward operating bases with dozens of troop convoy casualties resulting from these convoy missions every month. The U.S. Air Force reported that over 30,000 pallet positions per month go unused due to limited use of airdrop operations. The number of available aircraft pallet positions is equal to 60,000 truck pallets which, if used for airdrop operations, would result in a 20% reduction in convoy movements further resulting in a 20% reduction in convoy deaths. Given these numbers, the JIEDDO 10K ICDS program, which would utilize standard Army inventory equipment for airdrop operations from high altitudes, was created.

One reason for the limited use of airdrop operations in the warzone is the threat to aircraft when flying within small arms fire and shoulder launched missile range. For this reason, all airdrop operations are conducted at extremely low altitudes, which is a hard requirement for a large aircraft to meet when flying within mountainous regions, or at altitudes of 18,000 ft Mean Sea Level (MSL) or higher. Unfortunately, high altitude airdrop missions using standard Army inventory equipment were not possible due to the drift associated with parachutes such as the G-11 or the Low Cost Airdrop System – Low Velocity (LCADS-LV) when opening at 18,000 ft MSL. The purpose of the JIEDDO 10K ICDS program was to create a means to use these parachutes in a High Altitude Low Opening (HALO) configuration.

Another factor which has limited airdrop operations within the warzone is the need to recover expensive hardware and parachutes for reuse. As recovery has proven to be a complicated undertaking that, in many cases, occurs days after the mission is complete, a new airdrop method utilizing one-time use equipment was desired for missions where recovery is virtually impossible without risking lives. One of the underlying principles of the JIEDDO 10K ICDS program was the concept of utilizing one-time use parachutes, rigging equipment, and platforms, all of which use the least amount of metal possible in order to limit the amount of Improvised Explosive Device (IED) material left behind.

The JIEDDO 10K ICDS Program was created with the following goals: (1) create one-time use airdrop systems using Army inventory equipment, (2) be capable of dropping from altitudes up to 18,000 ft MSL, (3) land within 400 meters (m) Circular Error Probable (CEP) of the target point, (4) be capable of landing 70-90 feet per second (fps) for High Velocity (HV) airdrop and land 28.5 fps or less for Low Velocity (LV) airdrop, and (5) be capable of dropping 2,200-10,000 lbs of cargo. Given these guidelines, LV and HV airdrop systems and one-time use airdrop platforms were developed from Army inventory equipment while a method to drop HALO configuration loads was also created.

II. Airdrop System Descriptions

The JIEDDO 10K ICDS program consists of four different airdrop systems and four different airdrop platforms. Three of the four airdrop systems are HALO systems intended to utilize a drogue parachute from altitudes up to 18,000 ft MSL and the Wireless Activation Device (WAD) to trigger a pyrotechnic cutter to deploy recovery parachutes at approximately 1,500 ft AGL for a soft landing of 28.5 fps or less. The three HALO airdrop systems include: the LCADS HALO System[1], the G-11 HALO System, and the G-12 HALO System. The fourth airdrop system within the program is the Skirt Reefed G-12. The Skirt Reefed G-12 is intended to be a HV airdrop system throughout the entire descent. This system is intended to be dropped from altitudes up to 18,000 ft MSL and impact the ground at approximately 70-90 fps.

A. LCADS HALO System

The LCADS HALO System is a family of systems that utilizes the LCADS-LV parachute as the recovery parachute. The system can be used as a single recovery parachute or in clusters to meet four payload weight ranges: single recovery parachute for 2,200-lb airdrop, a cluster of two parachutes for 5,000 lbs, a cluster of three parachutes for 7,500 lbs, and a cluster of four parachutes for 10,000 lbs. The single recovery parachute is paired with a Low Cost Airdrop System – High Velocity (LCADS-HV) parachute as the drogue parachute, as shown in Figure 1, while the other LCADS HALO Systems utilize a 28-ft Ring Slot as the drogue parachute, as shown in Figure 2.

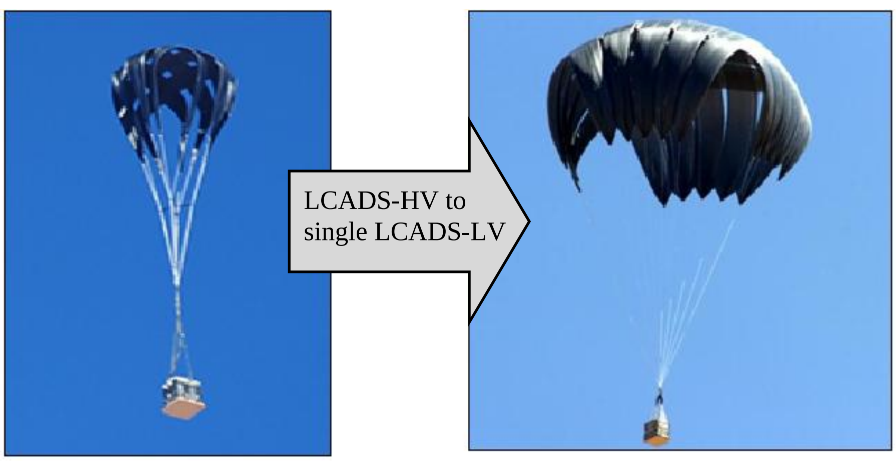

Figure 1. Transition from LCADS-HV to LCADS-LV System

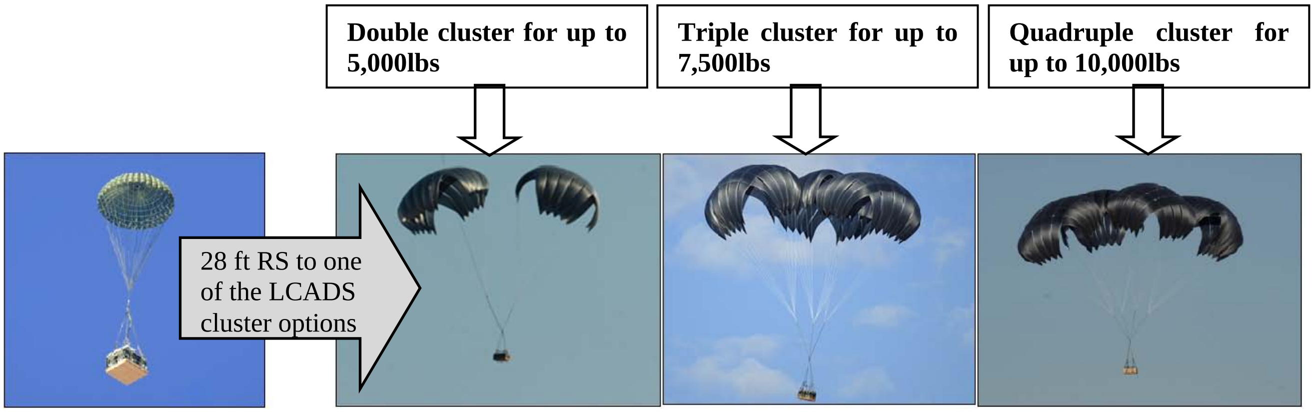

Figure 2. Transition from 28 ft Ring Slot to 5K LCADS, 7.5K LCADS, or 10K LCADS HALO Systems

B. G-11 HALO System

The G-11 HALO System is a family of systems that utilizes the standard G-11B parachute as the recovery parachute. The system can be used with a single G-11B as the recovery parachute to deliver 5,000 lbs of cargo on one platform or two G-11B parachutes can be clustered to deliver 10,000 lbs of cargo on one platform, as shown in Figure 3. Both systems utilize a 28-ft Ring Slot parachute as the drogue.

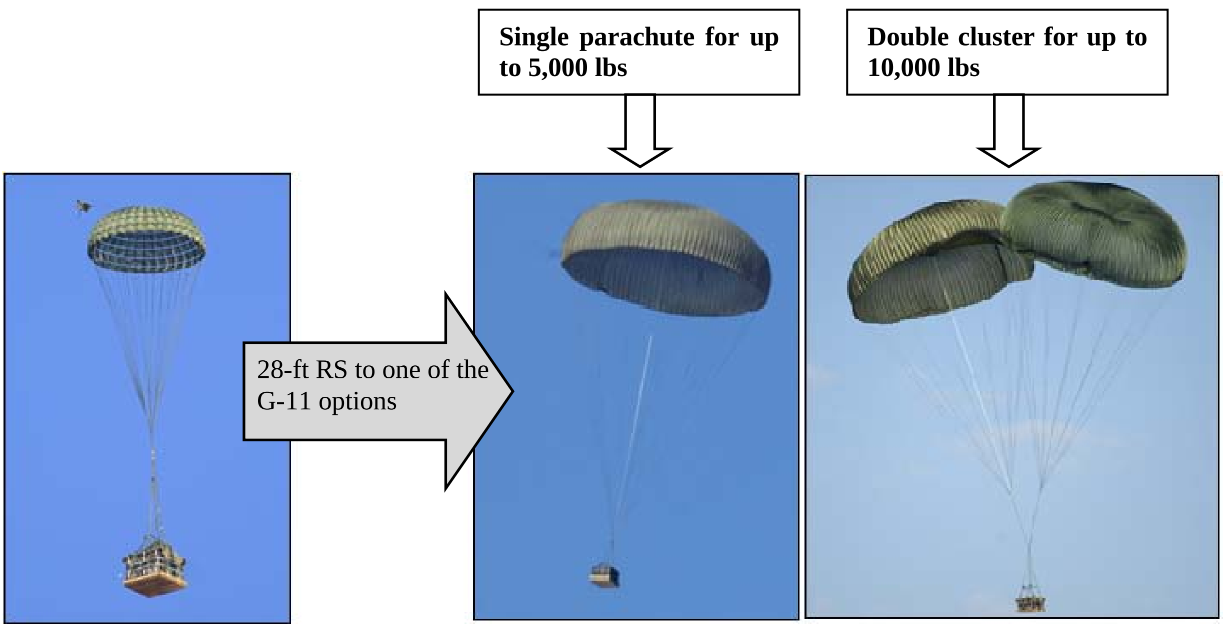

Figure 3. Transition from 28-ft Ring Slot to 5K G-11 or 10K G-11 HALO Systems

C. G-12 HALO System

The G-12 HALO System utilizes a standard G-12E configuration. A 15-ft Ring Slot is utilized as the drogue for this system, as shown in Figure 4, which is rated to drop 2,200 lbs. The system exits the aircraft at altitudes up to 18,000 ft MSL and falls under the 15-ft Ring Slot until the WAD triggers the A-15E zero second cutter at approximately 1,500 ft AGL. The cutter then releases the G-12E for soft landing.

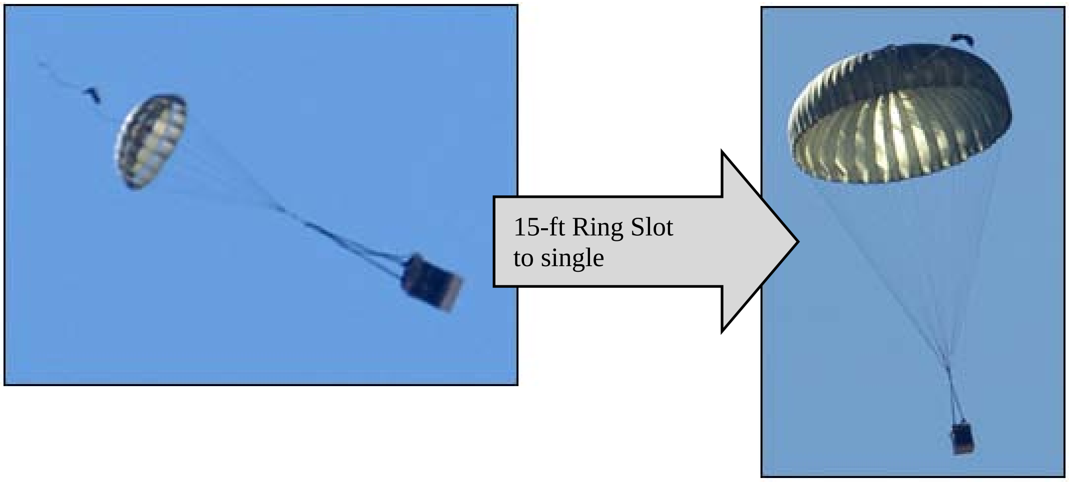

Figure 4. Transition from 15 ft Ring Slot to G-12 HALO System

D. Skirt Reefed G-12 System

The Skirt Reefed G-12 System utilizes the G-12 parachute packed in accordance with Humanitarian Airdrop Procedures[2] with a slight variation in the reefing line material used. After several tests and many failures, the 9/16-inch tubular nylon and 2 turns of ½-inch tubular nylon options were replaced with 1 inch tubular nylon. A 68 inch pilot parachute is used as the drogue chute for this system. The 68-inch pilot parachute exits the aircraft and immediately pulls the Skirt Reefed G-12 from its deployment bag, as shown in Figure 5. The G-12 inflates and remains reefed for the remainder of the drop. The Skirt Reefed G-12 System is rated to drop 3,500 lbs.

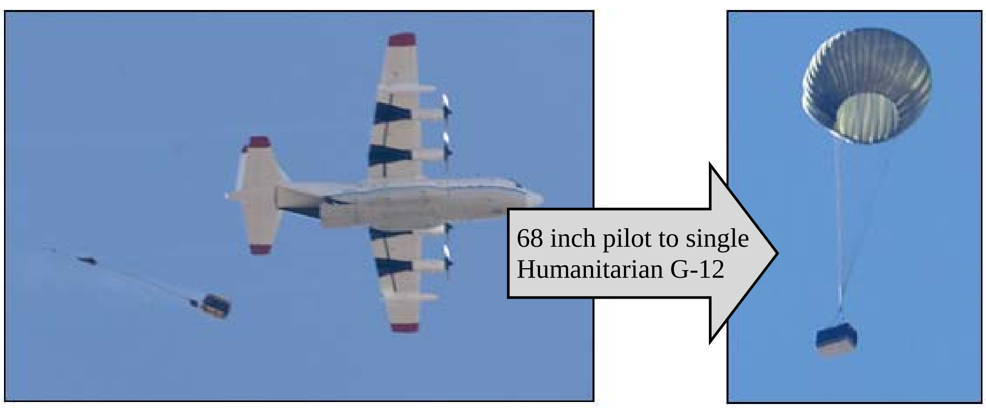

Figure 5. Transition from 68-inch Pilot Parachute to Skirt Reefed G-12 System

E. Platforms

Two standard airdrop platforms and two one-time use plywood airdrop platforms are utilized for the JIEDDO 10K ICDS Program. The 48”x48” standard skidboard along with a single A-22 container is utilized with the G-12 HALO system and the 2K LCADS-LV HALO System. The 48”x96” standard skidboard with two A-22 containers is utilized with the Skirt Reefed G-12 System.

The two one-time use plywood platforms were designed specifically for the JIEDDO 10K ICDS Program to fit within C-130 E, H, and J model aircraft, as well as C-17 aircraft. The 88”x96” platforms are made of four sheets of ½- inch AC grade plywood, and glue and can be utilized in C-130 E and H model aircraft, as well as C-17 aircraft. The 96”x108” platforms are made of five sheets of ½-inch AC grade plywood and glue and can be utilized in C-130 J aircraft. Both one-time use plywood platforms utilize four A-22 containers to maintain the cargo, and both can be used with the G-11 HALO Systems and the LCADS-LV HALO Systems. One of these platforms, set up in the

Roller Test Facility, is shown in Figure 6. All platforms in the program were designed to be one-time use, throw away items that do not need to be recovered. For additional cost savings, all systems within the program are approved to replace the standard A-22 container with the Low Cost Container.

Figure 6. One-Time Use Plywood Platform Set Up in Roller Test Facility

III. Wireless Activation Device

As previously mentioned, the Wireless Activation Device (WAD) is the item within the 10K ICDS system that fires an electrically triggered pyrotechnic cutter after a pre-programmed time. It was custom made from Commercial-Off-The-Shelf (COTS) components and is one of the only items across all three ICDS HALO systems that is not standard Army equipment. At the time of ICDS concept formulation, it was envisioned that a potential user would be given a kit containing a WAD, a compatible cutter, and rigging instructions to execute 10K ICDS drops. The WAD would be configured wirelessly through 802.11b communication or via a toggle switch located on the face of the item.

The original WAD concept is shown in Figure 7 and is based on the ATMEL AVR Butterfly. This board is nominally an evaluation tool used for demonstrating the capabilities of the ATmega169 hardware but provided an immediately available development platform for a short timeframe program like 10K ICDS. Onboard peripherals such as the Liquid Crystal Display (LCD), five position joystick, flash and Electrically Erasable Programmable Read-Only Memory (EEPROM) chips, Universal Asynchronous Receiver/Transmitter (UART) interface, analog to digital (ADC) converter, and Real Time Clock (RTC) provide a very powerful basis on which to construct designs. The hardware, coupled with exceptional documentation and a large user community, facilitated development that could potentially be ported to more ruggedized platforms.

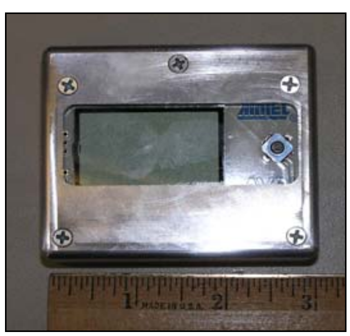

Figure 7. Original Wireless Activation Device Configuration

The system configuration was governed by a set of lanyards, one to apply power and the other to signal a timer to begin countdown. The user could input a desired drogue time by leaving the timer lanyard in, removing the power lanyard, and manipulating the toggle switch. During operations, the power lanyard is removed prior to system deployment. Countdown is triggered when the timer lanyard is pulled by the system, which was rigged to pull as soon as the drogue started to deploy. When the timer expires, a sufficient firing charge is applied to the pyrotechnic (shown in Figure 8) and the secondary decelerator system is deployed.

Figure 8. Roberts Research A-15E Zero Second Electric Cutter

The original WAD passed all USAF certifications and was altitude tested up to 24,500 ft MSL. Airdrop testing results were very positive, validating the concept of the WAD. Further design, ruggedizing and production tasks were transferred to Stara Technologies of Gilbert, AZ. Stara specializes in the design and implementation of electromechanical devices and produced a hardened, more capable version of the WAD, pictured in Figure 9. This new device has been extensively airdrop tested at the U.S. Army Yuma Proving Ground and incorporated into the Joint Precision Airdrop System - Mission Planner (JPADS-MP) to allow wireless communications and device configuration from the Air Force Navigator located in the aircraft cockpit.

Figure 9. Stara's Wireless Activation Device

The major drawback that affected both the original and current versions of the WAD is the rigging position. The primary failure mode is attributed to disconnection of the wiring responsible for pyrotechnic activation due to the dynamics of system deployment. Several mitigation techniques have been developed and applied to prevent system failure with very good results to date.

Given the successful integration and testing of the hardened version of the WAD, concepts learned in the 10K ICDS program are currently being applied to the 30K Ballistic Precision Aerial Delivery System (BPADS) with

encouraging results. Ongoing efforts include WAD miniaturization, software modifications to minimize power use, and application to other airdrop systems.

IV. Joint Precision Airdrop System Mission Planner

The USAF refers to any standard Container Delivery System (CDS) airdrop that uses the JPADS-MP[3] as Improved CDS, or, ICDS. The JPADS-MP, shown in Figure 10, is a combination of hardware and software that allows users to deploy dropsondes and receive real-time wind data and then uses this information to produce a Computed Aerial Release Point (CARP). The mission planner ingests a four dimensional forecast file provided by the Air Force Weather Agency (AFWA). The software can mesh this forecast model with any additional weather data provided by the user to generate an updated weather model. After this has been completed, the mission planner can apply the model of a specific parachute to this wind field and accurately predict its trajectory. Once this trajectory is combined with the desired Impact Point (IP), the software generates a point in space where the ballistic system must be released in order to reach the IP, this is the CARP. For guided systems, due to the large lift to drag ratio of parafoils, there is an entire area where the system can be released from to reach the IP. In these cases, the mission planner generates a Launch Acceptability Region (LAR), and as long as the system is dispatched within this LAR, it will be able to reach its target.

Figure 10. JPADS-MP Hardware

The concept of employment for the 10K ICDS systems within the mission planner was based on the software having weather forecast data for the area the system would be dropped, an accurate model of the HALO ballistic system, and a wireless connection with the WAD. If the software had all three of these components, the mission planner would know: how long it would take for the drogue chute to reach a steady state velocity, what that steady state velocity was as a function of the forecasted atmospheric conditions, and what altitude the second stage needed to be deployed at. From this, the software can calculate a time to program the WAD which can then be uploaded wirelessly to the WAD from the mission planner. If the mission calls for a deviation from the original mission, the user simply has to input the new release conditions (i.e. drop altitude), generate a new CARP, and send the new time to the WAD. This allows the users the greatest flexibility in the air while operating in a combat environment.

During initial system testing, while the mission planner software developers were working on the implementation of the WAD and specific models for each type of system, the custom ballistic model within the mission planner was used to generate CARPs. While not quite as good as a system specific model, the custom ballistic model is a good approximation, allowing for easy changes in parameters and supporting up to four stages. As shown in Figure 11, the user can input roll out time, the weight lost at each stage, the canopy characteristics of each stage, the transition times, and the altitude loss for each stage. Figure 11 is an example of a G-11 HALO system, all the system parameters were determined based on flight and video data of previous drops. The altitude

loss of the first stage is the drop altitude minus the IP altitude minus the altitude at which the second stage deploys, all in MSL. Although not officially scored, drops conducted using the custom ballistic model had very good results; this helped put confidence in the data that was being entered into model, as it would later be the basis for the system specific models.

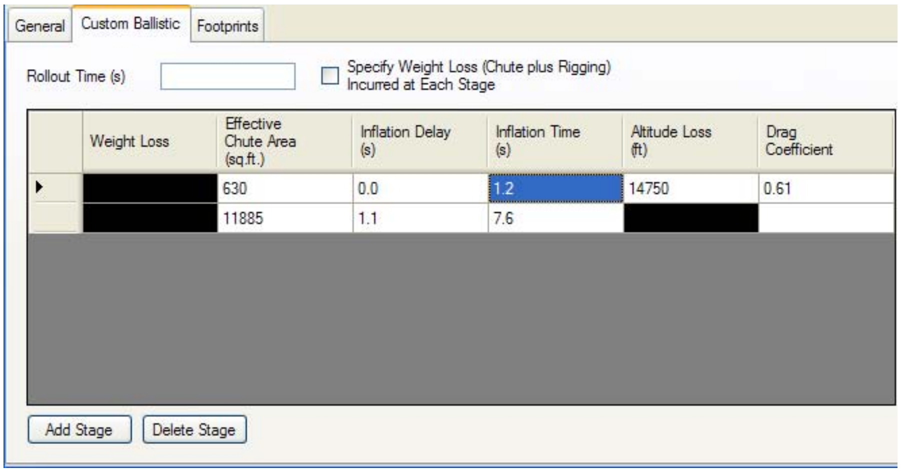

Figure 11. JPADS-MP Custom Ballistic Inputs

Figure 12 shows the final integrated graphical user interface (GUI) for the 10K ICDS systems. This is from a mission planned during the first week of a user evaluation and this is version 6.4.1 of the JPADS-MP. From this view, the user can input the type of platform used, the total rigged weight of the system, and the internet protocol (IP) address of the WAD unit for that specific system. Once the MP computes a CARP for the system, the gray area circled in red below will display the calculated time, known as Time Under Drogue, that will be sent to the WAD. This will allow the JPADS-MP operator the ability to visually confirm that the WAD is set to the correct time, but will prevent the operator from accidently changing this time from the mission planner. A manual override of the WAD is possible, but a different time cannot be sent wirelessly from the MP. The system characteristics that were derived during testing and the second stage opening altitude are coded into the software and cannot be changed by the user. A user evaluation was conducted on 10K ICDS using this version of the JPADS-MP.

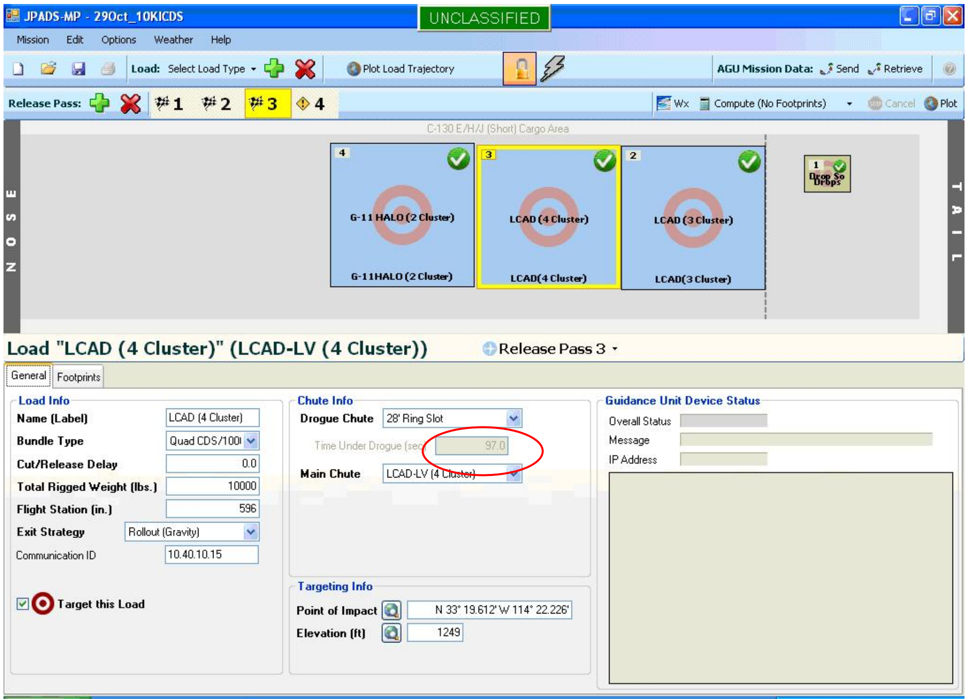

Figure 12. Screenshot of the completed GUI for a HALO System

V. Testing and Results

During the JIEDDO 10K ICDS Program, 14 test weeks were conducted, three at Red Lake Drop Zone in Kingman, AZ and eleven at Corral Drop Zone at the U.S. Army Yuma Proving Ground, Yuma, AZ. During the test weeks, a total of 165 airdrops were conducted. Table 1 shows the number of individual systems dropped during the program.

Table 1. Drop Numbers by System Type

System Name	Number of Drops
Double G-11 HALO System	32
Single G-11 HALO System	11
G-12 HALO System	12
Skirt Reefed G-12 System	47
10K LCADS HALO System	25
7.5K LCADS HALO System	23
5K LCADS HALO System	7

During the first four drop weeks, the systems were tested for functionality. After failures occurred, changes were made to equipment and rigging procedures to prevent the same malfunctions from occurring again. Throughout this timeframe, the LCADS-LV deployment bag was found to be a problem. While loading the platforms onboard a C-130 aircraft, it was discovered that, due to the large parachute pack volume, the LCADS-LV deployment bag overhung beyond the pallet footprint, causing problems with platform positioning on the aircraft. The overhang became a significant issue when three platforms could not fit onboard at one time due to the excess space the overhang required and the Air Force's need for the platforms to line up next to each other to meet aircraft rigging procedures. The LCADS-LV deployment bag was therefore redesigned so the parachute pack volume could

decrease in width and increase in height which allows four LCADS-LV parachutes to sit side by side on top of a 88”x96” load without overhang.

The Skirt Reefed G-12 also caused significant problems during the initial drop weeks. Several malfunctions, in which the reefing line would break upon opening, occurred at the beginning of the program. After many different tests and several calculations, it was determined that the single turn of 9/16 inch tubular nylon that was being utilized as a reefing line needed to be replaced with a 1 inch tubular nylon reefing line. After the change was made, no other failures were reported with the system except one load where a rigging error occurred. The Skirt Reefed G-12 was then certified to 3,500 lbs.

During drop weeks 5-11, the 10K ICDS systems were tested at maximum payload capacity for functionality with the JPADS-MP and the WAD from altitudes up to 17,500 ft MSL. Rigging of the WAD continued to be improved through week 9 during which time the system designs were frozen and rigging procedures were finalized. TSPI[4] data was gathered on each system for integration with the JPADS-MP through drop week 10. During this data gathering period, the Generic HALO Model was utilized in the mission planner to create the CARP for each system. Over these drop weeks, the JIEDDO 10K ICDS systems began to meet distance to target goals of 400 m CEP while consistently meeting payload capacity and landing rate of descent goals.

Week 11 was the first test of the JPADS-MP formal integration with the JIEDDO 10K ICDS systems. Each system had a distinct model within the MP software and could therefore be programmed with the MP based on system performance data gathered during previous drop weeks. The JIEDDO 10K ICDS integration into the JPADS-MP was successful with only a few small modifications that were required for more accurate system performance. At the end of week eleven the systems were ready to move into formal evaluation.

The final three drop weeks were Operational Utility Evaluation (OUE) test weeks. An OUE is a test sponsored by the U.S. Air Force to determine reliability and confidence levels for particular systems. Given the operational need at the current time, the U.S. Air Force chose to evaluate the performance of the 10K LCADS HALO System, the 7.5K LCADS HALO System, the Double G-11 HALO System, and the Skirt Reefed G-12 System. The goal of the OUE testing was to reach 90% reliability and 80% confidence for all of the systems listed above. The lower weight systems were set aside for further testing to begin in summer 2009.

Formal results from the OUEs are still pending from the U.S. Air Force but preliminary reports from the primary test facility, the U.S. Army Yuma Proving Ground, show the Double G-11 HALO System, the 10K LCADS HALO System, and the 7.5K LCADS HALO System all met the 90% reliability and 80% confidence threshold. The loads all landed within a maximum of 349 m of the target, well within the 400 m CEP goal, and produced results as close as 34 m from the impact point. Figures 13, 14, and 15 show distance to target results for each individual system type. Of note, malfunctions due to rigging and software errors were not included in the results as per U.S. Air Force guidance.

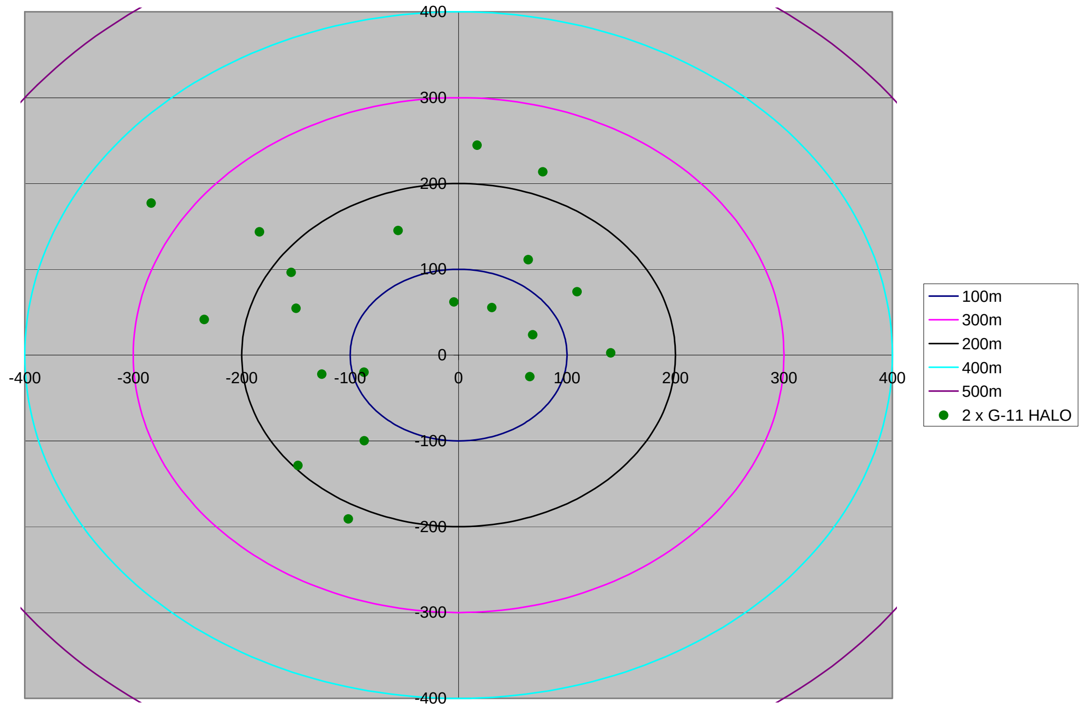

Figure 11. **Distance to Target Results for the Double G-11 HALO System**

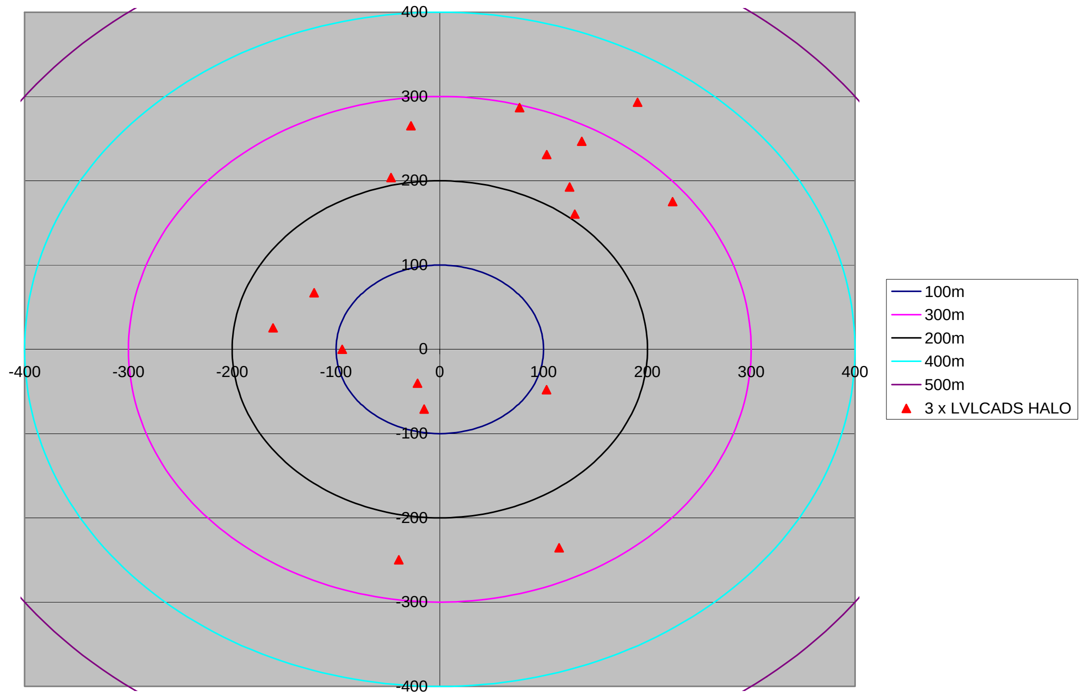

Figure 12. **Distance to Target Results for the 7.5K HALO LCADS System**

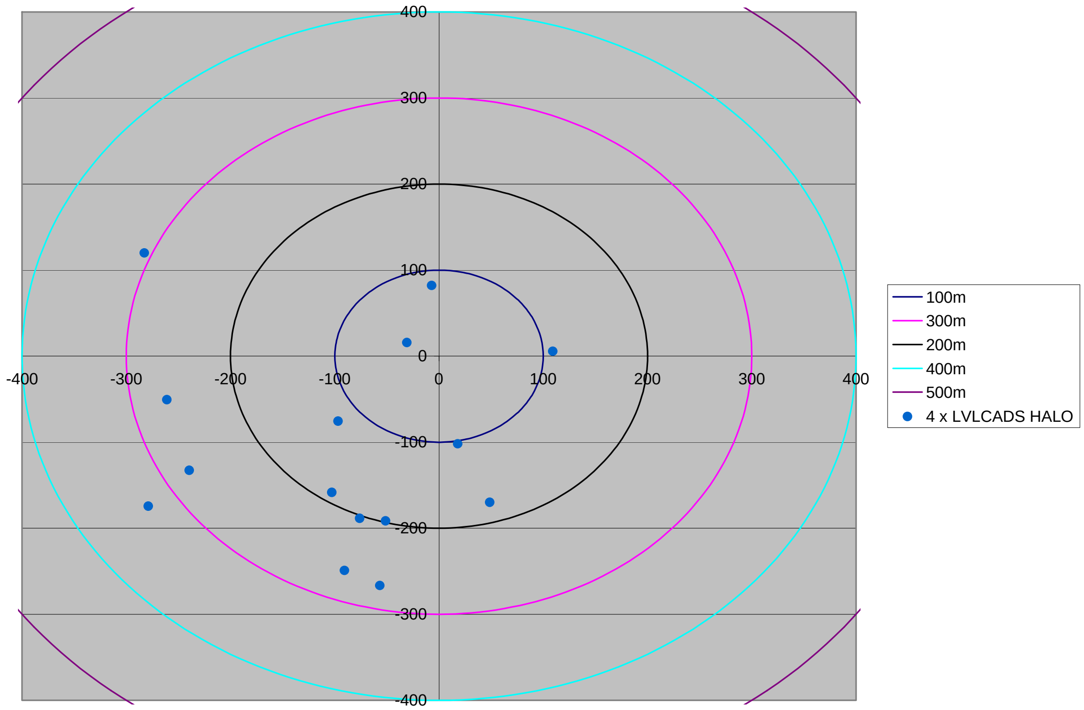

Figure 15. Distance to Target Results for 10K LCADS HALO System

The Skirt Reefed G-12 did not meet the confidence and reliability standard set for the program. There is some discussion about the JPADS-MP software used to create the CARP for the system. In many cases, the systems that landed outside of 400m, landed in clusters. The clusters included loads that were dropped on the same CARP, one pass after another. The U.S. Air Force is continuing to investigate this issue and more information will be available when the final OUE report is released. Figure 16 shows the distance to target results for the Skirt Reefed G-12 System.

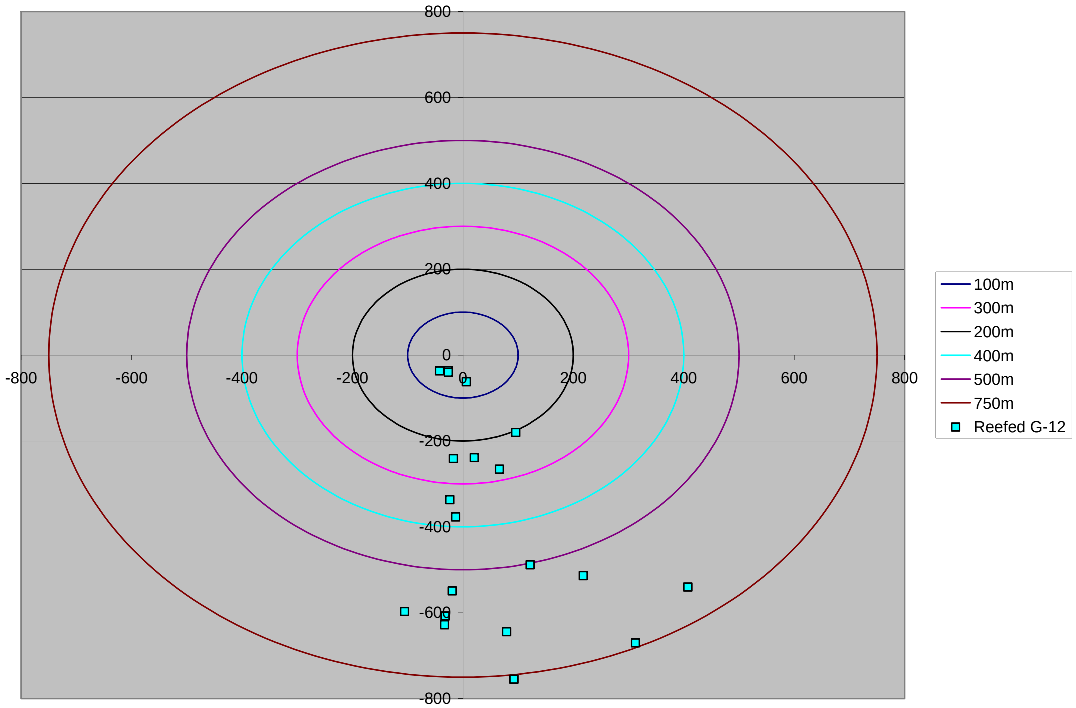

Figure 16. Distance to Target Results for Skirt Reefed G-12 System

In order to generate an accurate model within the JPADS-MP, the software developer had to be provided with specific parameters that were derived from the test drops. These parameters were: stabilization time, altitude loss, forward throw, canopy characteristics to determine steady state rate of fall, inflation times for both stages and the transition time between stages. This data was obtained at YPG using three or four Kineto Tracking Mounts (KTMs), which tracked the same payload from exit. The data from the mounts was then triangulated to come up with a single set of data that contained time, space, and position information (TSPI) as well as detailed video of the airdrop event. This data was then normalized so X-axis was the direction of flight at the moment of exit, the Y-axis was out the left wingtip and the Z-axis was relative to the center of the dropzone we were testing on. This information was also normalized to zero wind, standard day conditions by using balloon files at or near the time and location of the drop and weather observations. Stabilization time is defined as the time between aircraft exit to when the system reaches approximately 90% of its steady-state velocity and is determined based on velocity data versus time as well as video data. Altitude loss is defined as the difference along the Z-axis between the altitude at system exit and the altitude at stabilization. Altitude loss was calculated by taking the difference in z-position at each point. Forward throw is magnitude of the X and Y vectors from aircraft exit to system stabilization. A good way to characterize a parachute at a steady state velocity is by a drag term (SC_D). This term is the drag coefficient of the parachute times the effective surface area of the parachute. After the parachute is stabilized, the system is no longer accelerating and is falling at an equilibrium velocity, at this point, the drag force is equal to the weight, as shown in the equation below. The weight (W), the magnitude of the velocity in the z direction (U), and the atmospheric density (ρ) are all known based on the standard day corrected TSPI data. Currently there is no easy way to measure the true surface area of a parachute in flight, particularly one that is reefed to generate a non-standard geometry such as the Reefed G-12 system. As such, by combining the surface area (S) and the drag coefficient (C_D) into one term, it eliminates the need to determine one more value and as long as this term remains intact in all calculations throughout a model, it remains valid. With this drag term in the model, the software can easily predict a steady state velocity at any given weight and altitude.

$$D = W = \frac{1}{2}\rho V^2 SC_D$$

$$SC_D = \frac{2W}{\rho V^2}$$

Equation 1. Drag equation during steady state descent and re-written to define the drag term

It is important to note that the drag term that is derived using this method is a combination of platform and parachute drag. For the purposes of mission planning, this was ignored due to the system configuration for each platform being locked; therefore, these systems can only be dropped with platforms of very similar dimensions. Otherwise, the area of the platform should be noted and one would have to approximate the drag coefficient for the platform and subtract out the SC_D of the platform from what was observed during testing.

Inflation times for each stage are determined from video data. It is the difference in time from line stretch of the canopy to the first full open configuration. Transition time is also taken from video data in a similar fashion, it is the difference in time between the release of the first stage and line stretch of the canopy for the second stage. The processing of this data for each drop was done by both NSRDEC and YPG personnel. YPG set up KTMs, collected the TSPI and video data, normalized all data and processed stabilization time, altitude loss and forward through. The processed TSPI data and video footage was sent to NSRDEC, where the drag term for each chute was calculated, as well as the inflation and transition times. NSRDEC compiled all data and sent the average for each value per system to the software developer for coding into the mission planner.

VI. Conclusions

During the JIEDDO 10K ICDS Program, two new one-time use plywood platforms were developed along with a Wireless Activation Device to accommodate the extended drogue fall time of a HALO system. Standard Army inventory parachutes were utilized with small modifications made to the LCADS-LV deployment bag and the reefing line of the Skirt Reefed G-12. Overall, the program produced four different one-time use airdrop systems that can be utilized for 2,200-10,000-lb cargo airdrop. The systems can be used for emergency resupply, regular supply deliveries, or humanitarian aid in both wartime and peacetime. Although the program was designed to help reduce convoys, the systems could be used stateside for disaster relief. In general, the systems met and exceeded the goals set forth for the program and upon final approval could be utilized in the warzone by the end of 4th Quarter Fiscal Year 2009. The impact of this program on reducing the number of convoys will not be known for quite some time, but it is important to note that this 10K ICDS capability gives another tool to the warfighter.

Acknowledgments

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